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Articulating Communities: Sociocultural Perspectives on Science Education

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Part I: Sociocultural Perspectives on Science Education

What does it mean to take a sociocultural perspective on science education? Most basically it means viewing science, science education, and research on science education as human social activities conducted within institutional and cultural frameworks.

What is the scope of a sociocultural perspective on science education? Let us take the key terms of the previous broad description as our starting points. What does it mean to view the objects of our concern as "social activities"? In a research perspective it means, first of all, formulating questions about the role of social interaction in teaching and learning science and in studying the world, whether in classrooms or research laboratories. It also means giving substantial theoretical weight to the role of social interaction: seeing it, as in the Vygotskyan tradition (Vygotsky, 1963; Leontiev, 1978; Cole, 1996), to be central and necessary to learning and not merely ancillary. Similarly, it means seeing the scientific study of the world as itself inseparable from the social organization of scientists' activities, as is done in the work of Bruno Latour and many other contemporary sociologists and historians of science (e.g., Latour, 1987; Lynch & Woolgar, 1990, Shapin & Schaffer, 1985). But this is only the beginning.

Interpersonal social interaction, whether collaboration in a laboratory or dialogue in a classroom, is only the smallest scale of the social. Sociocultural theory proposes that such cooperative human activity is only possible because we all grow up and live within larger-scale social organizations, or institutions: family, school, church, community center, research lab, university, corporation, and (depending on your particular theory) perhaps also city, state, global economy, and even a potentially globe-spanning Internet chatroom or listserv group. Our lives within these institutions and their associated communities give us tools for making sense of and to those around us: languages, pictorial conventions, belief systems, value systems, and specialized discourses and practices. Collectively such tools for living—our social semiotic resource systems and our socially meaningful ways of using them—constitute the culture of a community. Taking an ecological view of communities, we should also include as parts of such

an ecosocial system all the artifacts and natural species and materials people employ in making use of these tools. Finally, sociocultural theory emphasizes that all human activity functions on multiple scales, from the physiological to the interactional to the organizational to the ecological, and so also on the corresponding time scales from the momentary to the biographical, historical, and evolutionary.

How we learn, how we talk and graph and walk and dance, what we believe and what we value are all both unique to us and to each occasion, but also usually somehow typical of people who have led lives like ours: people of our time and place, of our gender, class, and race (although with the serious caveats described below), of our own age, our customary education and religious training, our mixture of cultural heritages, and all the cultures of all the communities small and large in which we have lived. However, for each similarity there is also an implied difference: Every community is heterogeneous, and no individual learns and enacts all the roles in an institution. Cultures articulate across diverse subcommunities; they are never uniform or universally shared in their entirety among all or even most members; rather, they constitute an organization of heterogeneity (cf. Wallace, 1970). Our individual ways of living and making meaning are different according not only to which communities we have lived in, but also to which roles we chose or were assigned to by others—how we presented ourselves and how we were seen and treated by others. Because communities also organize themselves through conflict as well as through cooperation, we are often prevented from learning to see the world as some other members of our community see it; we may even be led to believe that ours is the only way of seeing or doing, or at least that it is the best way.

A sociocultural perspective on science education is skeptical and critical. Its most basic belief is that we do not know why we act as we do; we only know a few local reasons on a certain time scale and within a limited range of contexts. We do not know all the other reasons that arise from the functioning of our actions in far larger and more distant contexts and on longer time scales. As a research perspective this view seeks to elucidate the problems that arise from our limited view of the larger systems we inhabit, and to identify just how our actions do also function on many larger scales.

Sociocultural perspectives include the social-interactional, the organizational, and the sociological; the social-developmental, the biographical, and the historical; the linguistic, the semiotic, and the cultural. For many researchers they also include the political, the legal, and the economic, either separately or as implicit in one of the others.

Intellectual Origins

Sociocultural perspectives on science and science education in their contemporary forms (see discussions of some exemplary sociocultural research projects in science education below) derive mainly from developments in the social and human sciences since the 1960s. Because many researchers in science education are better trained in psychology, especially cognitive psychology, than in these other disciplines, it helps to understand their divergence. Jerome Bruner (1990) provided a useful account of how initial hopes in the late 1960s and 1970s for a general synthesis of cognitive and sociocultural perspectives in developmental psychology were disappointed as cognitivist research increasingly ignored sociocultural factors in the 1980s and turned toward a pure Cartesian mentalism, especially in the United States. At the same time, however, there was a great renaissance of sociocultural research in other fields highly relevant to science education.

The view that science represents a uniquely valid approach to knowledge, disconnected from social institutions, their politics, and wider cultural beliefs and values was strongly

challenged by research in the history of science (e.g., Shapin & Schaffer, 1985), the sociology of science (e.g., Latour, 1987; Lynch & Woolgar, 1990), and ethnoscience studies in cultural anthropology (e.g., Hutchins, 1980), and contemporary science studies (e.g., Haraway, 1989, 1991, 1999). Historians, sociologists, and cultural anthropologists came increasingly to see that science had to be understood as a very human activity whose focus of interest and theoretical dispositions in any historical period were, and are, very much a part of and not apart from the dominant cultural and political issues of the day. Moreover, the core sense-making process at the heart of scientific investigation was seen to critically involve instrumentation and technologies, in effect distributing cognition between persons and artifacts, and persons and persons, mediated by artifacts, discourses, symbolic representations, and the like.

Meanwhile, the view of science education (and education in general) as a second socialization or specialist enculturation into a subcommunity was developed out of anthropological theory (e.g., Spindler, 1987; Lave, 1988) and neo-Vygotskyan perspectives in developmental psychology (e.g., Cole, 1996; Wertsch, 1991; Rogoff, 1990), in opposition to asocial views of autonomous cognitive development. Piaget's view of the autonomous child-scientist constructing a Kantian epistemology from direct experience and Platonic logical schemas was revised along Vygotskyan lines to take into account the social and cultural origins of learners' logical, linguistic, and semiotic resources and models—learned from more experienced social partners—and the actual role of social interaction in learning and normal development. Nor was this an idealized view of social interaction as autonomous minds meeting in a rational parliament of equal individuals, but instead a richer and more complex notion of learning-in-community, often among unequal participants, with a significant role assigned to power relationships and differences of age, class, gender and sexuality, language, and cultural background.

Finally, along with all the social sciences in this period (cf. Foucault, 1969; Geertz, 1983), both science education and the new science studies (in history and sociology) took the linguistic turn and began to examine how people learned to talk and write the languages of science and meaningfully and cooperatively engage in its wide range of subculturally specific activities (e.g., observing, experimenting, publishing) and signifying practices (data tabulation, graphing, etc.). In place of a Chomskyan view of language as an automatic, gene-guided machine for correct syntax, people who were studying the *functions* of language in social interaction (e.g., Halliday, 1978; Martin, 1992; Schegloff, 1991; Mishler, 1984; Lemke, 1990; Bazerman, 1988) began to see language as a culturally transmitted resource for making meaning socially (e.g., Gee, 1990; Lemke, 1995) that was also useful for talking oneself through science problems. Language, however, was just one such tool; science and science learning are in fact best characterized by their rich synthesis of linguistic, mathematical, and visual representations (Lynch & Woolgar, 1990; Lemke, 1998a, 1999). In the sociocultural view, what matters to learning and doing science is primarily the socially learned cultural traditions of what kinds of discourses and representations are useful and how to use them, far more than whatever brain mechanisms may be active while we are doing so.

Perspectives on Science

What sorts of research questions do these perspectives pose about science itself? I believe that what best characterizes any approach to research is its questions. The means and methods of trying to answer the questions change with our ingenuity as researchers. The answers we come up with may be of enormous local importance in some time and place, but I would always look with greater skepticism on claims to have found general and abstract, much less universal

answers. Therefore, whether we are talking about sociocultural approaches to science itself, or to science education (see below), the key differences with other perspectives lie not so much in constrasting claims about the object of study (as they do when the object of study, as in physics, is relatively invariant from instance to instance) as in the posing of different sets of questions about it. Look at each of the following questions as a question about science, and as a question about science education. Ask yourself in each case how important the question is, how relevant it is to achieving the goals of science education research, and to what extent it is addressed by other approaches in our field:

1. What is scientific activity/science education as a social institution, and what is its relationship to other institutions?
2. What practices, beliefs, and values constitute the culture of science/science education in a given time and place, and how does this culture change across historical time?
3. How does the subculture of science/science education fit into the overall cultural ecology of a larger community? With what other subcultural systems is it allied or in conflict?
4. How is the specialized language of science/science education and its forms of writing and discourse similar to those of other subcommunities and different from them? Why? With what larger-scale social consequences?
5. How do the metaphors and practices of the scientific community influence the kinds of research questions that are asked in particular historical periods, or help determine which kinds of people feel attracted to or excluded from its culture?
6. How is science/science education as a community dependent on economic and political forces outside it, and how does it both resist and accommodate to this dependence?
7. How has science/science education as a culture, including its beliefs about legitimate methods and questions, and its beliefs about its objects of study, been shaped historically by the overrepresentation and underrepresentation in its ranks of different social categories of people: men and women, Europeans and non-Europeans, wealthier and poorer classes, young and old?
8. How does science/science education as an institution and a culture define the kinds of personal identities it welcomes and supports, and in what respects is science/science education more and less compatible with masculine versus feminine identities, middle-class versus working-class identities, and the global spectrum of national and ethnic cultural identities?

In answering these questions, we should also ask ourselves *which* sciences we are thinking of. Can we generalize about science as such, or is each different science unique? I tend to agree with the arguments by philosopher Sandra Harding (1986) that too much of what is said to characterize science as such in fact characterizes mainly physics as a paradigm science, and that physics is an ‘‘atypical science.’’

Science Education

Each of these questions can be posed both about science and about science education, and about the latter both as a teaching practice and as a research field. What sorts of implications would various answers to these questions have for the teaching of science and for research on science education?

We might ask, for example, to what extent students acquire frameworks within which to think critically about science, in general and in its details, in the absence of sociocultural perspectives on science? However much we may teach them about electrical circuits, redox

reactions, or genetic recombination, or even about controlled experimentation and graphical analysis of quantitative covariation, how much better able does this really make them to decide when they should trust expert opinion and when they should be skeptical of it? For all that the factual science curriculum is teaching them, are our students any more knowledgeable about the economic, sociological, technological, and political role of science in the modern world? If we teach more rigorously about acids and bases, but do not tell students anything about the historical origins of these concepts or the economic impact of technologies based on them, is the scientific literacy we are producing really going to be useful to our students as citizens? The most sophisticated view of knowledge available to us today says that it is a falsification of the nature of science to teach concepts outside of their social, economic, historical, and technological contexts. Concepts taught in this way are relatively useless in life, however well they may seem to be understood on a test.

If we turn from implications for curriculum to implications for learning theory, a sociocultural approach requires that we ask ourselves some tough questions about what kinds of personal identity and cultural values our science teaching accepts, respects, or is compatible with.

Our goal is science for all, but what does this mean if our particular view of science is too aggressively masculine to sit well with many students' identities? Too narrowly rationalistic to accomodate spiritual longings? Too technicist, abstract, and formalist for a wide range of humanistic, esthetic, sensualist, and pragmatic dispositions? Must all students love machines, numbers, predictability, and control to be welcome in our construction of what science must be? Do we have to continue to ignore the well-attested and documented (e.g., Wechsler, 1977; Tauber, 1996; John-Steiner, 1985) esthetic, intuitive, and emotional components of scientific creativity in our teaching methods?

Science education research has embraced cognitive psychology with almost unseemly haste, but there is little research on the *affective* response of students to our teaching, and on what exactly is happening as so many students get put off by our approach to science at just the age when they begin to consolidate their adult identities. Moreover, science education is increasingly a global enterprise, and even in one country, students today more and more often come from diverse cultural backgrounds. How welcoming is our received tradition of what science must be and how it must be taught of the beliefs and values of other, especially non-European cultures? Or even of non–middle-class subcultures (cf. Heath, 1983)? How critically are we reflecting on the fact that our science education subculture's acceptance of the current political movement toward more requirements and more high-stakes testing often appears to students as an essentially more coercive approach? Where is our *ethical* response as science educators to such issues? Where is our *intellectual* response as researchers to the problem of understanding the frequent conflicts between our view of science and our students' views of themselves?

What about Learning?

Science education researchers who see the principal focus of their work as an inquiry into student learning and how to promote more and better learning may have missed that focus in my account of sociocultural perspectives. The concept of learning can be useful, but it can also unnecessarily narrow our enterprise. Science education represents a massive institutional effort on a society-wide scale. It does not just affect individual learners; it also has important economic, military, political, and cultural effects. Why science education is as it is, what the contents of our curricula emphasize, how we are funded (or underfunded), how our membership is selected, what constraints are placed on us by political agencies (standards, testing,

accountability, mandatory years of study, teacher qualifications), what values we are allowed or encouraged to promote, and how strongly we are supported or opposed by the community cannot be understood by a focus on the efficiency of student learning alone.

Even if we choose to ignore the larger-scale contexts in which we work, we cannot ignore the ways in which student learning is also embedded in those contexts. Student interest in, attitudes toward, and motivation toward science, and student willingness to entertain particular conceptual accounts of phenomena depend on community beliefs, acceptable identities, and the consequences for a student's life outside the classroom (and inside it) of how they respond to our well-intentioned but often uninformed efforts at directing their learning: uninformed insofar as we do not take into account that learning is not just a matter of whether we can understand a scientific account, but also of whether our social and cultural options in life make it in our interest to do so.

An apparent assumption of conceptual change perspectives in science education is that people can simply change their views on one topic or in one scientific domain, without the need to change anything else about their lives or their identities. This modularism runs contrary to the experience of sociocultural research. Let me give a simple but telling example: the evolutionist-creationist controversy. To adopt an evolutionist view of human origins is not, for a creationist, just a matter of changing your mind about the facts, or about what constitutes an economical and rational explanation of the facts. It would mean changing a core element of your identity as a Bible-believing (fundamentalist) Christian. It would mean breaking an essential bond with your community (and with your god). It could lead to social ostracism and the ruin of your business or job prospects. It could complicate your family life or your marriage chances. Although I am slightly overdramatizing here (substitute adopting a progressive secularist view of the acceptability of gay lifestyles to appreciate the more extreme potential consequences), the point is that beliefs about the natural and social world have coevolved in cultures along with the entire complex network of social practices that bind a community together. The Renaissance Church did not oppose Galileo just because it disagreed with his conclusions about the motions of celestial bodies. There was a lot more at stake than rational choices among competing theories.

Changing your mind is not simply a matter of rational decision making. It is a social process with social consequences. It is not simply about what is right or what is true in the narrow rationalist sense; it is always also about who we are, about who we like, about who treats us with respect, about how we feel about ourselves and others. In a community, individuals are not simply free to change their minds. The practical reality is that we are dependent on one another for our survival, and all cultures reflect this fact by making the viability of beliefs contingent on their consequences for the community. This is no different in fact within the scientific research community than it is anywhere else. It is another falsification of science to pretend to students that anyone can or should live by extreme rationalist principles. It is often unrealistic even to pretend that classrooms themselves are closed communities which are free to change their collective minds. Students and teachers need to understand how science and science education are always a part of larger communities and their cultures, including the sense in which they take sides in social and cultural conflicts that extend far beyond the classroom.

I will return to this important issue at the end of this discussion.

Science Education Research and the Sociocultural Perspective

In the past 2 decades science education research has begun to address some of the sociocultural issues raised in the previous section. To get a rough idea of the extent of this

Table 1

Keyword(s)	Culture, Cultural	Social [Issues]	Language	Race, Racial
Items found	1836	2532	2201	484

engagement, it is instructive to look at the numbers of items retrieved by searches of the ERIC database (1966–1999) for "science education" and some key terms (Table 1). For comparison, "science education AND cognition" retrieved 3,058 items. A few other results of interest for "science education AND [other terms]" are in Table 2.

In the index to the fairly comprehensive recent *International Handbook of Science Education* (Fraser & Tobin, 1998), "cultural issues" has about as many page citations as "curriculum reform," and "social perspectives" as many as "constructivism"; "discourse" has a few more than "conceptual change." By and large, work in the sociocultural perspective is found mainly in the 1980s and 1990s, and appears to be supplementing if not supplanting the earlier heavy emphasis on individual learning and cognition.

What are some of the key areas of sociocultural research in science education in the past decade? Social interaction perspectives center mainly on classroom discourse (e.g., Lemke, 1990; Kamen et al., 1997; Roth, 1995, 1996, 1998), but there is also considerable interest in language and science education more generally (cf. Sutton, 1992, 1998). Wider sociological concerns include research on minorities in science education (Baker, 1998; Gallard, Viggiano, Graham, Stewart, & Vigliano, 1998) and gender equity issues (Parker, Rennie, & Harding, 1995; Keeves & Kotte, 1992). These two approaches have fruitfully intersected in research on science education for language-minority students (e.g., Lee & Fradd, 1998).

By far the largest focus of attention seems to have been on cultural issues, primarily on hypotheses of cultural conflict between the normative culture of science and the community cultures of Africans and African-Americans, various Hispanic groups, Asians and Asian-Americans, Pacific Islanders, and Native Americans (Aikenhead, 1996; Allen & Crawley, 1998; Atwater, 1994; Barba, 1993; Cobern, 1996; Costa, 1995; and so forth). Prominent here is the work of researchers who are themselves from partially non-Eurocultural backgrounds (e.g., Jegede & Okebukola, Lee, Ogawa, Ogunniyi, Lim, Olarewadju and many others; for detailed references see the collection of symposium papers organized by Aikenhead, Jegede, & Allen, 1999). There are also many contributions by members of groups that have been traditionally underrepresented in science and academic research, especially those who participate in the cultural systems of various Latin American and Afro-American traditions. Science education research as an institution is gradually widening its range of contributing perspectives toward a more truly global reach that is also inclusive of the viewpoints of many national minorities.

Nevertheless, there are still many sociocultural issues not addressed in depth by the research community, particularly direct engagement with issues of social class culture, nonstandard

Table 2

Keyword(s)	Discourse	Ideology	Social Class	Religion
Items found	190	61	28	297

dialect speakers, and racial attitudes and conflicts (on the racial economy of science, see the impressive collection edited by Harding, 1993). Moreover, there seems to be some tendency in the literature to apply only one type of sociocultural analysis for each social group, neglecting the role of the others. For example, in the U.S. literature, we hear far more about race in relation to African-Americans than we do about language or social class; far more about language in the case of Hispanic groups than we hear about race or class; and far more about culture for Asian-Americans or Native Americans than about race, language, or class. To some extent these imbalances may reflect only the early stage of these studies, but a self-reflexive application of the sociocultural perspective itself should make us worry that they may also reflect deep-seated ideological assumptions in the cultures of many researchers.

I should not be using terms such as *class*, *gender*, *sexuality*, and especially *race*, or even in many contexts *culture* and *language*, without problematizing them. None of these notions has objective definitions; all of them represent potentially misleading and harmful oversimplifications of the complexity of human similarities and differences. All of them owe their origins and historical prominence to explicitly political rather than scientific agendas. Every research study which frames itself in these terms should also be an inquiry into the limitations of applicability of the concepts themselves, refining and replacing them according to the salient features of the data at hand. Every researcher who uses them should have investigated their histories and be familiar with the relevant critiques of their validity. This is not often enough the case in the science education literature.

Science education researchers are not often enough formally trained in the disciplines from which sociocultural perspectives and research methods derive. Most of us are self-taught or have learned these matters second-hand from others who are also not fully trained in sociology, anthropology, applied linguistics, political economy, or cultural studies. Too often we do not know where the bodies are buried. Younger researchers may even be unfamiliar with the intellectual history that reveals the origins (briefly described above) of the sociocultural perspectives now in use in science education research, if only because few doctoral programs in science education require students to read sociology as well as psychology, to learn ethnographic and especially linguistic and semiotic methods of research as well as statistical ones, and to know as much about the political economy of science education as they know about constructivism or collaborative learning.

By contrast, in the papers for the recent symposium on Culture Studies in Science Education at the National Association for Research in Science Teaching (Aikenhead, 1999) it was important to see references not just to the canonical cognitive psychologists and philosophers of science that science education researchers traditionally study, but also to Bourdieu, Habermas, Foucault, Latour, Traweek, Spindler, Geertz, Halliday, Gee, Harding, van Manen, Wertsch, and others, as well as to work in other areas of education research which have made use of sociocultural perspectives (e.g., Apple, Cummins, Delpit, Freire, Garcia, Giroux, Green, Hicks, Irvine, Kincheloe, Ladson-Billings, Phillips, Tharp, and Wolcott among many more).

It is important that new researchers and established doctoral programs in science education recognize that familiarity with the classic literature of the contemporary social sciences (including cultural and social psychology, science studies, and cultural studies) is today as fundamental for reading the research literature of our field, for engaging in current dialogues about key issues, and for advancing our understanding of practical educational problems as is the work of cognitive psychologists or philosophers of science. Beyond this, our field should aspire to contribute to these disciplines and merit the same intellectual respect, accorded by the same exacting scholarly standards, as any other specialization within the human sciences. Our work should be sophisticated and significant enough to merit citation far beyond the borders of science

education. One recent review from outside the field suggests that by and large this is not yet the case (Turner & Sullenger, 1999).

Classroom Lessons and Lessons for the Future

How might a sophisticated sociocultural approach to science teaching make itself felt in educational practice? What kinds of research studies exemplify the insights that can make a difference for students' learning about science?

In 1978 I designed a research study supported by the National Science Foundation to investigate classroom interaction in science classes (Lemke, 1983a, 1990) using methods of discourse analysis based on social linguistics (Halliday, 1978, 1994). Unlike the better known theories of formal linguistics, social and functional linguistics regards our use of language as a socially and culturally contextualized meaning-making, in which language plays the part of a system of resources for meaningful verbal action. Concepts such as *register*, *genre*, and *semantic network* are used to establish connections between local contexts of situation (e.g., teacher and student social interaction, the expressed science content of a lesson episode), more global contexts of culture (e.g., expected teacher and student roles, canonical scientific discourses), and the lexical, grammatical, and discourse semantic properties of transcripts of actual classroom talk. This work built on earlier studies of give-and-take in classroom dialogue (Sinclair & Coulthard, 1975; Mehan, 1979) but was able to examine more precisely how scientific concepts and their relationships were communicated in talk. It demonstrated the close interdependence between teacher–student negotiations of social relationships (authority, humor, and stylistic expectations) and the communication of scientific ideas, as well as revealing the many forms of miscommunication and misunderstanding that happen in science classrooms (Lemke, 1990).

To complete this project it was necessary to develop and refine new methods of social discourse analysis (e.g., Lemke 1983b, 1985) and to move beyond considering classroom dialogue in isolation to take into account gestures, chalkboard diagrams, and what was written in the textbook (Lemke, 1987). From this work came a number of recommendations for classroom teaching, principally for giving students more opportunities for extended talk using the language of science. The subtleties of language which were pervasive in communicating scientific ideas pointed to the need for more serious consideration of the needs of students less fluent in English and even of those who use nonstandard community dialects. Closely related work has since demonstrated the educational relevance of social-class dialects (Hasan, 1988, 1995) and begun to investigate the role of mathematical symbolism and specialized visual representations, along with talk, in classroom learning and in professional scientific practice (for example, Roth, 1999a; O'Halloran, 1996, in press; Lemke, 1998a, 1999).

The work of Wolff-Michael Roth in science education (e.g., Roth 1998a, 1998b, 1999b, 1999c) has made sophisticated use of both discourse analysis perspectives and concepts developed by sociologists of science such as Bruno Latour to examine how students learn by collaborating in designing and building simple mechanical engineering projects (e.g., towers of glued soda straws; see also Kamen et al., 1997), how practical innovations and new ideas spread through a classroom community, how students and professionals use graphing as a tool for meaning making, as well as how students marshal evidence and argument. Less well known is the recent work of Kay O'Halloran (1996, in press) in mathematics education, which combines classroom discourse analysis with new efforts to interpret the relations between language and mathematical symbolisms and diagrams, but also goes further to make explicit comparisons of discourse and symbol use across gender and social class differences. The work of Gordon Wells (e.g., 1986, 1999, in press) has successfully integrated a discourse-based approach with research

on student learning in inquiry-oriented science curricula from a sociocultural perspective in the highly multicultural context of urban schools in Toronto. The work of these researchers may be taken as exemplary among the many excellent research programs that today pursue sociocultural approaches to classroom education and use discourse-based and semiotic research methodologies.

From this work and related studies in other areas of education (see Cazden, 1988; Sutton, 1992; Ogborn, Kress, Martins, & MacGillicudy, 1996) have come a wide variety of now indispensable tools for the analysis of verbal data, oral or written (see Lemke, 1998b, for an overview), as well as newer techniques for the study of the visual representations (e.g., Kress & van Leeuwen, 1996) that are pervasive in science (cf. Lynch & Woolgar, 1990; Lemke, 1998a). In a recent project (Cumming & Wyatt-Smith, 1998), 19 highly respected researchers from the United States, United Kingdom, and Australia analyzed videotape and documentary data (student notebooks, textbook excerpts, teacher overheads, and handouts) from a variety of theoretical and methodological perspectives to ascertain the literacy demands of the advanced secondary school curriculum and their social and cultural functions. (Several of these analyses will be published in a forthcoming special issue of the journal *Linguistics and Education*). Such multiple analysis projects (e.g., Santa Barbara Classroom Discourse Group, 1993; Kamen et al., 1997) are also increasingly common features of sociocultural research practice because the sociocultural perspective highlights the ways in which any single analysis necessarily represents a socially and culturally positioned and thereby inherently limited viewpoint. Unfortunately, few studies have yet attempted to incorporate viewpoints that range across the full spectrum of social and cultural differences to be found in science education today. We preach collaboration across differences as an exemplary way for students to study science, but we do not often enough practice it ourselves as a way to study science education.

Classroom studies have been a dominant focus of sociocultural research in science education, importantly supplemented by inteview-based studies (e.g., Baker & Leary, 1995, in which girls speak out about science and school science). There has also been pioneering work on collaborative learning mediated by computer networks (e.g., Scardamalia, 1992; Edelson, Pea, & Gomez, 1996), but sociocultural perspectives on science education should also push us to examine fundamentally different kinds of social arrangements for learning about science.

There is no ideal sociocultural science classroom in the sense that there might perhaps be one that is representative of HPS, science–technology–society, constructivist, or conceptual-change approaches to science education. Sociocultural approaches do emphasize the role of classroom communities and an understanding of the development over time of the unique social relationships and microcultures that characterize these communities, but the greatest promise of sociocultural approaches lies in looking both within and beyond the classroom. Unlike, for example, literacy education (cf. Egan-Robertson & Bloome, 1998), science education research has not as extensively investigated the relationships between home and school cultures, or between school science and professional science. We have not looked at science teaching from the experiential perspective of a student who spends most of every day, before and after science class, in other subject-area classes, in social interactions in school but outside the curriculum, and in life outside school. We have imagined that the few minutes of the science lesson somehow create an isolated and nearly autonomous learning universe, ignoring the sociocultural reality that students' beliefs, attitudes, values, and personal identities—all of which are critical to their achievement in science learning—are formed along trajectories that pass only briefly though our classes.

Sociocultural insights may in fact be antithetical in the long run to our present ways of organizing science education only in heterogeneous classroom communities. If we take

difference seriously, we should not be prescribing the same curriculum and methods for all students. We should not be trying to either ignore language differences or homogenize them, to ignore social class and heritage culture differences, or to eliminate them in favor of one dominant culture. Although we must help students to learn about difference and learn to work together collaboratively across differences, we cannot continue to use that as an excuse to ignore the different learning needs that difference engenders. A sociocultural perspective tells us that we should be doing research to discover the best ways to integrate science teaching that is responsive to different needs with teaching that addresses the challenges of a heterogeneous and diverse classroom community.

Diversity and its needs are not matters of exceptionality and exotic and radical difference. Diversity in some degree is the condition of every community. Our curricula and teaching methods, however, are by long tradition most closely adapted to the needs of middle- and upper-middle-class, culturally North European-American, fluent speakers of prestige dialects of English. I do not mean here just the goals of our curricula, about which there is appropriate political debate, but the means as well. We inherit a social ideology, especially in the United States, which says that by heroic efforts of underpaid teachers, it is possible to create classrooms of 30 to 40 students with an arbitrarily high degree of social, cultural, and linguistic diversity who will nevertheless learn science at exactly the same rate and with equally high and broadly distributed levels of achievement compared with, say, classrooms of 20 to 30 students who share substantially similar backgrounds and learning needs. On the other hand, we also inherit an organized school system which pays no attention to teaching students the lessons of working across age-diversity (e.g., cross-age tutoring, or mixed-age collaboration) or learning to connect school learning to learning and action outside school. We inherit a system of schooling that rips apart arduously constructed classroom communities and teacher–student social relationships every 4–9 months—almost as soon as they are well enough established to produce mutually supportive insights. The organized efforts of many people in our field today are focused on setting curriculum achievement standards and promulgating more intellectually authentic teaching methods, but more basic institutional, social, cultural, and linguistic prerequisites for school success are still not being taken seriously.

The most optimistic researchers in our field today are those working at the cutting edge of applying new information and communication technologies in science education. I share their optimism, but not because I believe that new kinds of learning experiences (modeling, simulation, remote-sensor data, data visualization, etc.) are sufficient to increase widespread interest in and success at science learning. My hope is that these new technologies will stimulate fundamental structural change in science education, adding to our present model of maximally heterogeneous classroom groups many new options: providing students with access to a diverse, global pool of ‘‘tele-mentors’’; enabling peer-group (including mixed-age) network-mediated long-term project work and electronic portfolio documentation of contributions, progress, and results; and facilitating individualized curricula and study paths, with wide latitude in expected time to completion. Such alternatives could fill a significant fraction of students’ learning time, making it possible for professional teachers to work more intensively with those who need special help, for heterogeneous classroom communities to take on more specialized functions and maintain continuity of social relationships over periods of years, and for schools relieved of some time and space pressures also to offer other essential services for more homogeneous groups of students with common needs.

Within this more flexible institutional framework, science education will likely need to develop several complementary approaches to assisting learning. We will still need curricula, activities, and teaching methods suited to the heterogeneous classroom and primarily teaching

the lessons of collaborative inquiry—but not also trying to do everything else for everyone. We will need interdisciplinary curricula and instructional materials support for the science-based components of thematic project studies, and for individual and for small-group learning in both face-to-face and network-mediated investigations. We will need standalone computer-aided instruction curricula, with topic modules and multiple pathways for linking ideas and developing conceptual relationships, rich information-access tools, intelligent tutoring modules, and links to resource pools of on-line human mentors. We will need specialized curricula and methods for students who are learning English at the same time they are learning science, at various levels of achievement in each. At the same time, we should also be developing alternative curricula and modules of all these types which address the special needs, interests, and developing identities of a wide variety of students: young students attempting advanced topics, adult learners starting with simple concepts, women of any age who may not feel welcome in the masculinized world of traditional science curricula, the large numbers of gay and lesbian students whose needs and perspectives are ignored not just by science education but by schooling in general, and all those members of our many distinct social cultures who wish to have their interests and values respected while they are learning science or any other subject.

New technologies are removing our excuses for not paying more attention to social, cultural, and linguistic differences and their importance to students. One size has never fit all in science education, and in my opinion the most urgent, challenging, and exciting agenda for science education in the first decades of the next century will be to diversify the range of ways in which a diverse population of people can come to understand, appreciate, and criticize science as a human activity, a social institution, a specialized culture, and a means of making sense of the vast complexity of our natural and social worlds.

Encounters with Complementary Perspectives in Science Education Research

This special section of the current *JRST* issue is in part also a dialogue among various research perspectives on science education. In what follows I respond to the articles in this issue by Nancy Brickhouse and by David Wong and his colleagues. Each of us also responds to the "conceptual change perspective," informed by the classic article by Posner, Strike, Hewson, and Gertzog (1982).

Sociocultural Perspectives on Feminist Approaches to Science Education

In her thoughtful and committed article in this issue, Nancy Brickhouse summarizes for us the history and motivations of feminist perspectives on science education. More than this, she sketches out how a synergy between situated cognition theory and feminist scholarship might address an even wider range of key issues in science education. Both of these approaches emphasize issues of identity development as central to learning, and identity conflicts as central to the failure of our schools to engage and educate specific segments of the population in making good use of science for their own purposes. Both regard the unit of analysis for learning not as an idealized, individualized Cartesian mind, but as material and symbolic activity in a material context and a socioculturally specific community. In both these regards you will easily recognize the close similarities to the approach I have been outlining here.

In one sense the sociocultural perspective seeks to include and subsume feminist and situated cognition approaches, and to articulate them with linguistic, semiotic, sociological, and cultural research on science and science education. However, there is a danger in every such intellectual imperialism: losing what is distinctive, and especially what is uniquely critical in

intellectual traditions with separate social histories. Feminism offers a profound critique of all of traditional intellectual culture: science, mathematics, literature, technology, education and schooling, and no less of linguistics, sociology, cultural anthropology, or psychology. There is a great deal we have yet to hear, spoken from women's location within our communities. Feminism and its distaff cousin, Queer Theory, add profoundly to the traditional concerns and perspectives of sociocultural theory: a concern for the fact that human beings make meaning with our own biologically and culturally different kinds of bodies, a perspective on knowing that includes bodily and culturally meaningful feelings as well as percepts and concepts as central to our epistemological repertoire, a relegitimation of sexuality as a core intellectual concern and human motive in interpersonal relations and learning, an honest confrontation with what structural inequities of power in a society mean at the personal and individual level, and an intellectual engagement with the reality of human pain and suffering.

Sociocultural theory also speaks to feminism, although cautiously, because it has not yet fully responded to the feminist critique of its own core assumptions (a critique moreover which is not yet fully articulated, but see Haraway, 1999). Feminism has learned, I think, from sociocultural theory not to assume that the experience of gender is the same in different times, places, and cultures, or homogeneous even within one time, place, and culture; there is systematic variation with age, class, race, and even religious and occupational subcultures. Accordingly, feminism also has to cope with the tension between needed political solidarities among women and an intellectual awareness that those solidarities are discursive constructions every bit as much as are the oppressive stereotypes they confront.

I want to respond here to just two of the specific challenges which Brickhouse's article presents to more traditional views of science education.

"After all, the point is not the facts," she writes in her account of David and the octopus stories. What *is* the point of learning what institutional science says about the natural world? For many students, it is to make use of those facts for their own purposes (in David's case, richer stories about an octopus and a hero), but our mainstream science education does not support the outbound trajectory toward a broad field of possible identities in a wider range of possible activities that use science. We say that we want students to taste the canonical scientist's way of using science (although in practice there is little of that and mostly in only abstractly simulated ways) (Lemke, 1994); but is that all we can manage to support across all the years students study science? Our rationalization for imposing a single possible scientific attitude and identity on all students and ignoring the many possible other ways of viewing and using science is neither honest nor believable from a sociocultural perspective. It is too easy to see how obviously economic interests dictate our inbound trajectory for student identity. We are too often being paid to make more scientists, engineers, and technicians, not better poets or wiser human beings.

Perhaps we could succeed better at science literacy for all if we supported the much wider range of uses for science learning that fit with the lives and identities of a much larger fraction of the population. We could identify and confront the masculine bias in paternalistic attitudes to students ("Why can't you grow up to be a scientist? I did!"), and its economic basis (noting that the Bureau of Labor Statistics does not publish next-decade projections of the national need for story writers); we could think more critically and more often about the larger-scale relationships between these phenomena.

Brickhouse later notes that the authors of *Our Bodies, Ourselves* also listened to women's experiences and integrated this information with more conventionally scientific information. This discussion helps us identify the sociocultural sense in which science and science education, as traditionally understood, may already have become either obsolete or overspecialized. The real and pressing problems of human communities are never merely technical, and can never be

articulated or solved solely by knowledge of that abstraction we call Nature. As Latour (1993) argued cogently, I think, we are long past the stage in human history when it was useful to artificially segregate the natural from the social world. To study natural phenomena as if *we* were not in society and as if *they* were not interacting with society, through us and through technologies that will amplify and ramify those interactions indefinitely and unpredictably in the human future, is today simply unscientific and irrational. Not to study women's health, global warming, nuclear power, or space exploration by the methods of both the natural and social sciences is pointless. We must teach students how to integrate interview data with biochemical assay data and how to critique particular assays in relation to their social functions as well as their ligand chemistry. We can identify the masculine bias in a biomedical science that has often unconsciously assumed that men were universal and generic *Homo sapiens*, and we can trace the artificial separation of natural and social sciences in relation to the economic and military usefulness of the former and the politically subversive potential of the latter. In either a feminist or a sociocultural perspective, we have to conclude that continuing to teach the sciences as autonomous disciplines will not prepare students for successful lives in the 21st century.

Education as an Experience

There are a number of common intellectual sources that connect my own view of sociocultural learning with the Deweyan perspectives developed by David Wong and the Deweyan Ideas Group (Wong et al., this issue). Both views are rooted in the epistemological traditions of American Pragmatism originating with Peirce: Making meaning is a material process, transactive between persons and things, and does not belong to an autonomous Cartesian parallel universe of purely mental realities. Both also take meaning making to be more than just reasoning; it is an aspect of total human activity that is also bodily and rich in affect (two dimensions also emphasized in feminist scholarship).

"An experience" in the special Deweyan sense Wong and his colleagues describe is always educational but it does not just add to our store of facts or bring about a rationally argued change of opinion; it also stirs us to a "heightened vitality." It makes an impact on us as human beings; it contributes to the development of our identities. Wong et al. extend and specify this Deweyan perspective further by noting that it prescribes a dynamical model of experiencing, inside the flow of time and events, with an anticipatory awareness that we are getting somewhere, and a sense of consummation (rather than mere cessation) when we have got wherever "there" turns out to be. A recent biological Idea (in the Deweyan sense; see below) is Rosen's (1985) notion of living systems as "anticipatory systems," which I interpret as meaning that our living experience is always a moment in processes on many time scales, some of which necessarily overlap into the future as physics reckons time, but which form part of our biological present (cf. Lemke, 2000). The longer time scales of human living mark processes such as identity development (as well as relationship development, family and community projects, and other agendas), and the material systems in which they occur are ecological and ecosocial ones, not single organisms or persons.

If education is to be based on this view of having Experiences, rather than just being dragged through a curriculum (which pretty clearly diminishes rather than heightens human vitality), science education needs to pay attention to Ideas rather than just to concepts. Concepts are abstract tools; Deweyan Ideas are exciting and they enable us to have new and richer experiences in the future. Ideas in this special sense are not just cognitive, they are behavioral (I would say actional) and affective as well. Having an idea is like being the protagonist in a heroic drama (perhaps too much so; see below). Good models of the dramatistic perspective on learning can be

found in the classic work of Kenneth Burke (e.g., 1966, 1969), who also developed closely related views of how we learn to see in new (and newly limited) ways though the screens or filters of our terminologies (see Stillar, 1998, for a synthesis of Burke with more familiar models of discourse analysis).

Experiences of dramas, or whole works of art, are ideal examples of what Dewey meant. Vygotsky (1971), too, turned to art as a paradigm for the social experience of meaning. However, what is the analogue in the case of science? Wong et al. seem to suggest that it is scientific concepts, perhaps Big Ideas. I would agree with this only if they mean something rather larger than a concept, something on the scale of a Discourse, or what is sometimes called a theory or a model, in which several concepts beautifully complement one another in complex mutually supportive relationships. We can diagram these artworks of science as static concept webs, but we experience them, initially and every time anew, as unfolding texts of argument and explanation, as beautiful prose works of scientific art. However, even that does not quite seem enough to me to evoke the heightened vitality we associate with an Experience in science. There are also the beautiful experiments of science, whether rendered as accounts of what happened, or experienced from idea to design to data and conclusions. It is the vital fusion of theory and experiment (or observation) that makes science truly a performance art. I do not think we in science education have paid much attention to understanding the esthetics of science or of learning. There is certainly a suprisingly large literature in which scientists themselves attest to the central and essential role of an esthetic dimension in their creative work (e.g., Wechsler, 1977; Tauber, 1996).

Why do we not? Why must science and science education define themselves as rejecting the educational ideals and methodological insights of the humanities? Who is attracted to science presented as purely rationalistic and affectless? (No human activity is affectless; rational-mindedness and dispassionateness, reasonability and tentativeness are affects.) What kinds of identities are recruited and what kinds excluded by this narrow view of science—one that is contradicted repeatedly by creative scientists? These are just the sorts of questions that a sociocultural perspective in science education (and often a feminist one as well) sets out to answer. The answers are historical, economic, political, and sociological. The cultures and identities of the sciences and the arts have also been pushed apart along many of the same dimensions of difference that separate stereotypes of what is masculine and what is feminine (rational/emotional, hard/soft, controlled/spontaneous, abstract/concrete, universal/particular, objective/subjective, profitable/pleasurable, stable/shifting, etc.). If authentic education about science is to work against the exaggerations of these stereotypes, it will have to become more humanistic in many of the ways that Deweyans endorse.

Two final cautions. First, having an exciting experience with science is valid and valuable in itself, but education must always be more than one great experience after another. Each small drama of experience must somehow play a part in still larger dramas on longer time scales. Unlike works of art or designed curricula, educations are always works-in-progress. How do we promote and support longer-term intellectual and personal development in a curriculum of great experiences? One suggestion is that our curricula must work to ensure greater continuity in students' ways of experiencing as they move from one classroom to another and from classroom to hallway to neighborhood to home (Lemke, in press). There is no more reason to believe that the habits of vital experiencing will automatically transfer to the rest of students' lives than that habits of technical reasoning will do so. What lasts for the long term in us is what we have learned how to remake for ourselves across many contexts. This is not only an argument for more multidisciplinary curricula, but for the curriculum to work more vigorously against the radical separation of school from the rest of students' lives. It is a Deweyan concern.

Second, in the dramatic metaphor for such experiences, we each find ourselves the hero or protagonist, achieving an insight; but do we also thereby learn ensemble acting, how the climax of the drama arises in real life from the interactions of many players? How do we synthesize the psychological insights of *Art as Experience* with the social and political ones of *Democracy and Education*? My point here is that a focus on personal feelings and even on individual intellectual excitement, whether in applications of Dewey or feminist theory, can easily tempt us back toward an individualistic view of learning. Even if we make clear that social interaction is an essential part of learning, we have a further responsibility to articulate how even feelings differ across communities because they are in part the artifacts of communities. Sociocultural theory must ask how we teach human beings to Have Experiences and engage with Ideas; it wants to know how the felt experiences of these human possibilities would differ from culture to culture, how comfortably they sit with differently configured and socially positioned identities, what social functions these very Deweyan notions themselves may play in the intellectual and political economies of their cultures of origin and export.

Changing More Than Our Minds

The conceptual change approach in science education began with the useful observation that many students come to the science classroom with alternative ways of understanding everyday phenomena. Part of the job of science education, it was argued, should be giving these students opportunities to change their minds on the basis of what the scientific tradition considers good evidence and valid argumentation. The result would be both conviction about the accepted scientific way of understanding these matters and also valuable experience with the scientific process of rational decision making, explanation, and theory building.

A sociocultural perspective offers some challenges to this optimistic view. First, there is the question of whether students' alternative conceptions and those of the European scientific tradition belong to any common framework within which there can be agreed upon criteria of evaluation. A choice between two scientific explanations can be made only because both belong to a common tradition, with agreed-upon rules of evidence and argumentation. In a larger sense all scientific explanations also belong to the culture of science, a culture that seeks particular kinds of knowledge for particular purposes. The cultures of everyday life also seek knowledge and explanation, but often for quite different purposes; their criteria of validity are also correspondingly different. When we move well outside the orbit of European-derived cultures, or even of middle-class subculture, the nature of what counts as knowledge and what qualifies as explanation may also be startlingly different.

A classic instance, of course, is the continuing debate over scientific evolutionary theory in biology versus fundamentalist Christian biblical literalism about Creation. This case represents not so much a conflict in the sphere of the everyday as a more serious example of incommensurable cultural criteria about explanation. Within evolutionary science, there are debates about punctuated equilibrium, selection versus self-organization, gradualism versus catastrophism. Some of these come close to posing paradigm shifts, which already imply changes in basic assumptions about what are the relevant questions and kinds of evidence. However, between evolutionary science and fundamentalist religion, there is almost no common ground. In the one case the purpose of accounts of, say, human origins is to provide a framework for the synthesis of diverse forms of specialist data (paleontological, genetic, geological, climatic, etc.). In the other case, the function of beliefs is to maintain the ground of moral behavior (according to the usual sociocultural theory) or to uphold one's faith in God and His Word (in the view

of believers). Hybrids such as creation science do not really bridge these incommensurable cultures.

Less dramatically, the culture of everyday life and commonsense reasoning also has different uses for explanatory concepts or accounts than does systematic science. Everyday reasoning is local; it does not require a global consistency among procedures or concepts across all practices and phenomena. It is enough if an account works in the domains where it is used. There are many other such differences. Historically, science and commonsense understanding have differed for centuries. Each thrives on its own ground.

Conceptual change models and linguistic or semiotic models in sociocultural theory are much more convergent. The former speaks of investigating "how a student's current ideas" interact with new ideas in the context of a "conceptual ecology" (Posner et al., 1982). Discourse theory has much to say about how concepts or themes interact semantically with one another, within and between discourse formations, and Foucault (1969) gave an elaborate analysis of the elements of such formations relevant to analyses of historical change in scientific and other discourses (see also Lemke, 1995, chap. 2). Even the emphasis in conceptual change models on the role of our meta-theories and epistemologies is a familiar sociocultural theme. The fundamental difference is that sociocultural models see students interacting with teachers (cf. Vygotsky vs. Piaget), each as representatives of communities that can be characterized in part by their belief systems, rather than either one set of ideas interacting with another or a sovereign individual ego freely choosing between beliefs and communities.

Many science educators believe that rationalism should be the sole basis of decision making not just in science, but in life and politics. In part, it is also because of cultural assumptions; Americans and many others in the English-speaking cultures particularly insist that the individual mind must be the natural unit of all valuing and meaning-making practices. Our heroic, romantic, and masculine myths glorify one man with the truth struggling against ignorance and error to triumph over all. Sociocultural research not only debunks these myths by doing detailed research on how new discourses, values, and practices really arise and spread in social networks, but also by asking how such myths and beliefs function in society as a whole, and what their economic and political implications are.

Brickhouse (this issue) has also noted that the very dichotomy between rational choice and the bodily feelings that both feminists and Deweyans see as fundamental to learning reflects a peculiarly narrow historical and cultural tradition. Reasonableness and tentativeness are surely feelings, too, and never found unmixed with other feelings (whether exhilaration or pride, steadiness, or humility) necessary to the scientific ideal. Logic gates do not describe what was once called the divine faculty of human Reason, and there is much more than the quantitative weighing of evidence to what we call scientific judgment. Belief is more than the acknowledgment of bare facts or an assent to logical relationships; it is a felt commitment, a component of identity, and a bond with a community.

Yes, we should give students opportunities to change their minds, but we should not do so unaware that we are thereby inviting them to join a particular subculture and its system of beliefs and values. We must also stop and consider whether we are, perhaps unnecessarily, making the price of admission to science the rejection of other essential components of students' identities and values, the bonds that link them to other communities and cultures. We cannot afford to continue to believe that our doors are wide open, that admission is equally free to all, that the only price we ask is hard work and logical thinking. We need to understand how the price is reckoned from their side of the differences that separate us. We also need to critically reexamine whether the particular view of scientific rationality we offer is an idealization, or a travesty, of the true scientific spirit.

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